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DESCRIPTION OF TEXTS OF AUXILIARY PROGRAMS FOR PROCESSING VIDEO INFORMATION: PART II. SUODH PROGRAM OF AUTOMATED SEPARATION OF QUASIHOMOGENEOUS FORMATIONS

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16. Abstract

This work describes the algorithm, block diagram, complete text and instructions for the use of a program of automated separation of quasihomogeneous formations from materials of multizonal remote sensing.

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DESCRIPTION AND TEXTS OF AUXILIARY PROGRAMS FOR PROCESSING VIDEO INFORMATION: PART II. SUODH PROGRAM OF AUTOMATED SEPARATION OF QUASIHOMOGENEOUS FORMATIONS

By

V. I. Borisenko and L. S. Chesalin

Introduction /3*

When observations are made from an aircraft or satellite the earth's surface seems to consist of individual sections, separated by various types of boundaries, roads, rivers, landmarks, tree-plantings, etc.

In examining the color photographs, or those synthesized in conventional colors, of fragments of the earth's surface one can find sections that have the same color. Black-and-white photographs or quasiphotographs [1] for each resolution component yield an idea on the intensity of the electromagnetic radiation in individual spectral zones reflected from the earth's surface. The system consisting of the recorder (human eye) and the analyzer (human brain), is capable of isolating individual section according to the color index, shape of the boundaries, texture, etc. This system is capable of grasping the entire picture as a whole or separating the image depending on the assigned or intuitive criteria. The system "eye-brain" can ignore individual sharp changes, and at the same time, note inconspicuous contours; it is capable of extrapolating open boundaries; it is easily adjusted to the different criteria of isolation or identification; it reacts differently to the changes in brightness or color index in individual sections of the image (i.e., it can exclude, or on the contrary, record the slightest changes). Knowledge of its operating principles

*Numbers in margin indicate pagination in original foreign text.

would provide invaluable assistance in constructing automated systems of video information processing, but since these principles are still not known, then different intuitive algorithms are of definite interest. This work describes the program for separation of quasihomogeneous formations, i.e., the formations whose spectral characteristics are constant on the average. /4

1. Description of Algorithm and Technique for Separating Quasihomogeneous Formations

The initial material for the operation of the given program is the video information in a standard color-superposition format [2], where each resolution component on the earth's surface is described by a color vector $(a_{ij})^k$ (i, j--number of lines and columns of image component, k--number of spectral ranges in which the radiation reflected from the given fragment is recorded.

In the definition of the quasihomogeneous formation [3] the existence is implied of a coherent set of image elements whose spectral characteristics $\hat{a}^e_{ij}$ differ little from the corresponding components of a certain vector (b^e). In other words, the coherent set of image components is considered to be a quasihomogeneous formation if all the points that depict each of its components in the measurement space are grouped fairly compactly, i.e., occupy a small volume around the point (b^e).

Different methods are possible for determining the hypercenters (b^e) of each quasihomogeneous formation: their a priori assignment, with the help of computation of the polymodal histogram peak centers, etc. We will dwell on the technique of a formalized determination of (b^e) based on the hypothesis of the existence of formations that are quasihomogeneous in the spectral sign.

It is evident from a definition of the quasihomogenous formation [3] that in a certain line or column at least several neighboring components must exist with close spectral characteristics. After uniting such components into a group /5 one can compute the mathematical expectation of their characteristics, that should be taken as $(\tilde{b}_s^e)$. Since the directions for an examination of the information according to lines or columns are not equivalent (since the video information is organized by lines on the magnetic tape), the following algorithm is suggested to determine the initial group of elements belonging to a certain quasihomogeneous formation. After the next block (line) of video information has been read, the

vector amount of mathematical expectation is computed for the intensity of the first L components of the line, and the quasidispersion of the spectral characteristics of these components is determined:

$$\tilde{b}_s^e = \frac{1}{L} \sum_{j=j_0}^{j_0+L} a_{ij}^e \quad , \qquad (1)$$

$$D = \frac{1}{K \cdot L} \sum_{e=1}^{K} K^e \sum_{j=j_0}^{j_0+L} \left| a_{ij}^e - \tilde{b}_s^e \right| . \qquad (2)$$

Here k--amount of spectral canals, 1--number of spectral canal, L--quantity of components taken as the minimum possible in the line for the existence of a quasihomogeneous formation, j_0--beginning number of component in the line of video information, k^e--weight coefficients.

After this the fulfillment is determined of the inequality that defines the degree of compactness in space of the multizonal measurements of the selected set of neighboring components in the line, i.e., the correctness of the inequality is checked

$$D < D_L \quad . \qquad (3)$$

Here D_L is the measure of heterogeneity adopted for the given image and corresponding to the average quasiseparation of the points from the hypercenter $(\tilde{b}^e_s)$. With fulfillment of inequality(3)the components from j_0 to j_0+L are considered to belong to a certain formation. If inequality (3) is not fulfilled the beginning number j_0 is increased by a unit and the process is repeated until /6
this inequality is fulfilled. The number of beginning components L (that participate in the computation $\tilde{b}_s^e$ and D) will be called the number of dispersion components, or simply the dispersion length.

After the inequality (3) is fulfilled, the process begins of increasing the given homogeneous formation with the hypercenter $(b_s)=(\tilde{b}_s)$. Each subsequent component in the line (a_{ij}) is studied for its affiliation to the given formation with number s; the fulfillment of the following inequality is verified for it

$$\frac{1}{K} \sum_{e=1}^{K} K^e \left| a_{ij}^e - b_s^e \right| = D < D_s \quad , \qquad (4)$$

where $j = j_0+L+1, j_0+L+2$ etc., D_s-- measure of heterogeneity, generally speaking, not coinciding with D_L. From our viewpoint it is expedient for D_s to be larger than D_L. The encountered component that does not satisfy (4) is viewed as a random malfunction, while if there are two neighboring components that do not satisfy (4), the process of forming a quasihomogeneous object with number s in the given line is considered to be finished, and certain additional characteristics of the formation are defined. The table whose structure will be described below has information on the isolated object, and the selection of a new quasihomogeneous formation begins. For this j is assigned a number that is a unit greater than the number of the last added component, and the process of searching for a new quasihomogeneous formation is repeated again.

The table that is formed after an examination of the next line, has the following appearance:

S_s	N_s	$CHAR_s$	KD_s	j_H^s	j_K^s	i_H^s	i_K^s	j_s^e	N_s^F

Its components have the following meaning: S--quantity of components of s-th quasihomogeneous formation, N_s--its number in the line, $CHAR_s$ and KD_s-- vector of the averaged spectral characteristics and vector of quasidispersion, /7
j_H^s, j_k^s--beginning and final number of components of the given object, i_H^s and i_k^s--number of line in which the search for the homogeneous objects was made. The meaning of the values N_s^F and j_s^e will be explained below.

After a review of the next line in the computer memory, analogous tables are simultaneously found for the current and previous lines (NEWTAB and OLDTAB). Now the quasihomogeneous formations for the column are united. For each component of the table OLDTAB a corresponding (for the column) component NEWTAB is sought, for which the fulfillment of the system of inequalities is verified:

$$
\begin{aligned}
(j_H^s)_{NEW} &< (j_K^s)_{OLD} \\
(j_K^s)_{NEW} &> (j_H^s)_{OLD}
\end{aligned}
\quad . \qquad (5)
$$

i.e., is verified if in (i+I)-th line the object that can become a continuation

of the τ-th object of the i-th line. If there is no such object, then the object with number τ is considered to be complete, and information about it is transferred to the table RESTAB for subsequent classification, while if such an object does exist, then the identity of the objects τ and s is verified; for this the quasidistance between their characteristics in the space of multispectral measurements is computed:

$$R = \frac{1}{K} \sum_{\ell=1}^{K} | b_{\tau}^{\ell} - b_{s}^{\ell} | \quad . \qquad (6)$$

If this distance is smaller than the assigned measure of heterogeneity D_c, the objects are united into one. This entails a certain reformation of the s-th component of NEWTAB:

1. The quantity of elements of the S_s formation is replaced by the sum S_s+S_{τ};

2. The characteristics of the object $CHAR_s$ and KD_s are recalculated into average characteristics of the summary formation; for this their vector amounts are added with the weight coefficients that are proportional to the areas of the coherent objects;

3. i_H^s is replaced by i_H^{τ}, j_s^e is assigned the value j_{τ}^e from OLDTAB. (During the formation of NEWTAB the number of the extreme column of the isolated object is entered into j_s^e). The presence of the numbers of lines i_H^s and i_k^s, between which the given object is located, and the numbers of the extreme column of the upper line of the object j_s^e facilitates the identification of the table with the initial material. Such coordinate correlation is necessary at the stage of further interpretation. /8

4. The so-called "birth number" of the given object is entered into N_s^F; it appears during the formation of a new quasihomogeneous formation that is not a continuation of the object from the previous line. The presence of this number in NEWTAB indicates that this object is already linked to the objects of the previous lines, and after a review of the entire table OLDTAB, the next numbers are assigned to the formations that are not a continuation.

The RESTAB table that is constructed analogously to NEWTAB or OLDTAB is formed from objects of OLDTAB that do not continue in the next line. Only j_H^s and j_k^s are

excluded from it, and N_s is formed with a rewriting of the next component OLDTAB into RESTAB. When the assigned number of components of RESTAB is filled, the information is released onto magnetic tape. Consequently, all the data on each object (area; spectral characteristics; location on the image; numbers obtained by the given object during its emergence and release onto the magnetic tape) are preserved for the subsequent classification.

At the same time as the review of the next line, another output tape is formed that is necessary for the display of the isolated quasihomogeneous formations. The length of the line of this tape is determined by the length of the line of initial material: two bytes are assigned to each color vector of the image; in these bytes the "birth" numbers of the given formation are entered. Thus, each line of the resulting magnetic tape is filled with numbers N_s^F, from which one can /9
always, after using RESTAB, determine the characteristics of each specific quasihomogeneous formation. The absence of numbers in certain components of the output tape indicates that these components do not belong to any of the isolated objects.

After the end of the review of the fragment whose coordinates (number of beginning and final lines and columns) are assigned from the controlling punched cards, the total area is computed for the separated quasihomogeneous objects P, the percentage relationship is determined for this total area P to the area of the entire fragment S_{fr}, and besides these two amounts, the number of separated objects N^F is also printed. This makes it possible (at the stage of determining the separation parameters) to evaluate the performance capacity of the given algorithm, and to make the appropriate corrections: increase or decrease D_1 and D_s, change L, etc. With the selected parameters the amount P shows the expediency of automated separation; the small value of P indicates either the incorrectness of the set task (search for quasihomogeneous formations where they do not exist), or that for the given fragment of the image, the parameters for separation were not successfully selected (if it is known a priori that the given material contains fairly many homogeneous formations).

The volume of the operational memory that is occupied by the program together with the regions of input-output is 3.5 bytes, so that the algorithm can be used on a computer with fairly small operational memory. The process of separation occurs on the ES-1020 computer at the rate of reading the magnetic tape with initial material.

The simplicity of the algorithm, replacement of expensive (in the sense of fast-response) operations of multiplication and evolution (in the formulas for computing distances) with simple operations of the moduli sum type--all of this /10 determines the high speed of the program realization of the suggested algorithm. As shown by the results of preliminary calculations, such a replacement is quite justified, since it provides a large saving of expended machine time without strongly affecting the accuracy of the separation.

The SUODH program was written in the ASSEMBLER language for the ES computer; its block-diagram is given in the appendix, and its text in a separate appendix. It was computed to process video information with any number of spectral (no more than 8) and arbitrary line length. The size of the RESTAB block is fixed (32 bytes), the number of blocks (objects) in one physical output tape recording is 32.

2. Instructions for Working with the SUODH Program

The parameters necessary for operation of the program are:

NST--beginning number of the line of the examined fragment.

KST--final number of the line.

NCT,KCT--numbers of beginning and end of columns (color vectors).

LCOL--number of spectral channels in studied material.

D_L--measure of heterogeneity (under conditions of measurement units) adopted to form the homogeneous object.

D_S--permissible deviation for the line necessary to determine the affiliation of the next component of the line to the formed homogeneous formation.

D_C--measure of heterogeneity that makes it possible to link the objects of the neighboring lines into one object.

LRAZ--number of dispersion components.

The amounts of the described parameters in the form of four-value whole /11 numbers must be packed on the controlling card in the following order:

$$LCOL, NST, NCT, LRAZ, D_L, D_S, KST, KCT.$$

Information input-output is written on a logical level [4], therefore, among the controlling cards of the assignment there must be perforated cards present that identify the input and output magnetic tapes, i.e., operators

// TTBL with indication of the names of the input and output files. The program guarantees recording of the tail markers on both output tapes after review of the last line of initial material indicated by the parameter KST.

The numbers of the lines and the columns in the output tape correspond to the numbers of the lines and the columns of the initial video information.

3. Suggested Variants of Program Modification

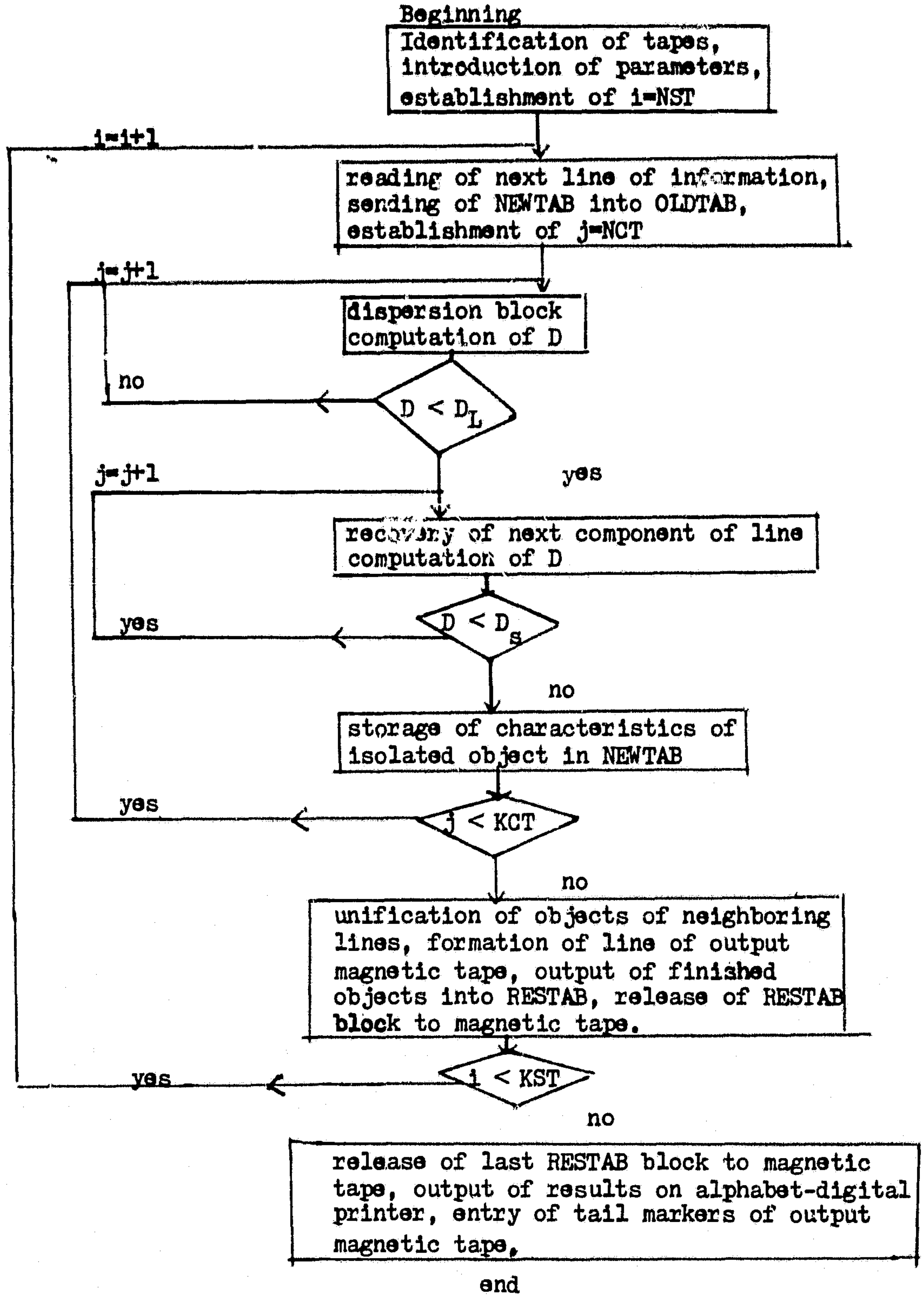
1. The weight coefficients K^e that serve to intensify the influence of individual channels participate in the algorithm for separation. In the described program variant their amount is the same. However, a whole series of reasons (a priori information on the greater importance of one or several channels as compared to the others; information on errors in the operation of one of the channels, etc) can result in the need to change individual (or all) the weight coefficients. Therefore, it is further suggested that weight coefficients be introduced from a separate punched card.

2. In the operational computer memory the tables NEWTAB and OLDTAB are assigned 800 bytes each for placement of information on 25 objects that are located in one line. However, in the localities characterized by great diversity of natural formations, there can be more homogeneous objects in one line than 25. It is /12
suggested that these files be transferred to the end of the program, and that the size of the memory set aside for them be expanded.

3. In the examined algorithm for separation of the quasihomogeneous formations, only the dispersion of the vector characteristics for the object was computed and stored in the memory. It is proposed that further perfection in the algorithm take into consideration the moments of higher orders as well. Their determination and storage requires additional writing of the computation block, and increase in the area of the memory that is occupied by one component of the table.

The authors are deeply grateful to Z. A. Stetsenko for assistance in setting up this work.

Appendix. Block Diagram of SUODH



References /14

1. Borisenko, V. I.; Bykov, A. V.; and Chesalin, L. S. "Certain Types of Preliminary Processing," Kosmicheskiye issledovaniya zemnykh resursov ["Space Studies of the Earth's Resources"], Moscow, izd-vo Nauka, 1973.

2. Zolotukhin, V. G.; et al., Opisaniye sistemy programm matematicheskoy obrabotki na EVM ES fotograficheskikh izobrazheniy Zemli, poluchennykh s kosmicheskikh apparatov (komplex SOFI) ["Description of System of Program for Mathematical Processing on ES Computer of Photographic Images of Earth Obtained from Space Vehicles (SOFI Complex)"], Preprint of the Institute of Space Research, USSR Academy of Sciences, Pr-336, Moscow, 1977.

3. Borisenko, V. I.; and Chesalin, L. S. "Algorithms of Thematic Interpretation of Multispectral Aerial Space Video Information," Kosmicheskiye issledovaniya, XVI, 3 (1978).

4. Dzhermeyn, Programmirovaniye on IVM/360 ["Programming on the IVM/360"], Moscow, izd-vo Mir, 1971.

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